Improved Techniques for Targeting Additional Observations to Improve Forecast Skill

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LONG-TERM GOAL

This project aims to improve ensemble forecast and adaptive observation techniques based on targeted diabatic singular vector analysis with a particular focus on severe weather events in the tropics and extratropics in the range 0–5 days.

OBJECTIVES

The first objective is to assess the extent to which ensemble forecasts of severe weather events in which initial error is represented by targeted singular vectors, and model error is represented by stochastic physics perturbations, can be relied on to include a member which is close to reality (in the range 0–5 days). The initial focus will be on tropical cyclone prediction.

A second objective is to investigate the effectiveness of targeted observing networks in the sensitive regions of the atmosphere defined by the singular vectors. The horizontal and vertical extent as well as the density of additional observations that are required to reduce the initial condition error to that of the best member of the ensemble will be studied. It will be assessed whether the assimilation system can be geared to more readily accept adaptive observations made in currently data sparse regions. Again, the initial focus will be on tropical cyclone prediction.

A third objective will be to study the impact that the formulation of the linearized diabatic terms in the tangent model and the choice of analysis error covariance norm at initial time has on the structure of the singular vectors.

Finally, it is hoped to be able to use the improved targeting techniques in real-time targeted

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observation experiments.

APPROACH

The ECMWF ensemble prediction system (EPS, Buizza et al. 1999) is designed to indentify and utilise sensitive initial perturbations (singular vectors). These can be targeted to optimise perturbation growth in a particular region of the atmosphere. The role of uncertainties in the formulation of physical processes in the model can be investigated using the stochastic physics component (Buizza et al. 1999) of the ECMWF Ensemble Prediction System.

Ensembles cases using targeted singular vectors will be run where some particular severe weather event occurred. From these cases, the 'best member' of the ensemble will be identified. Assuming that this is close to reality, the best member will be labeled as a surrogate 'true' state.

In the next step, synthetic (dropsonde or aerosonde) observations will be created from the perturbed analysis corresponding to the 'true' state. These observation will be made either at randomly chosen points, or at points where the singular vector perturbation is relatively large. The synthetic observations will be added to the observation database, and a new analysis will be created using 4DVAR.

The impact on the forecast of varying the number of synthetic observations and of observing just a subset of the variables wind, temperature and humidity will be studied. In addition, synthetic observations restricted to the near surface will also be studied.

New forecasts will be made from the analyses which include synthetic observations. The impact of targeting will be compared with the control and best member forecasts.

The technique generally outlined above is being first tested on forecasts of the tracks of tropical cyclones. Later it is planned to extend the study to forecasting severe weather events in the extratropics.

Jan Barkmeijer is studying the effect of including moist processes on the structure of singular vectors. Kamal Puri is examining tropical cyclone evolution with the ECMWF ensemble prediction system. Martin Leutbecher is investigating the effect of synthetic observations on the analyses and subsequent forecasts.

WORK COMPLETED

Puri et al. (1999) has investigated the sensitivity of tropical cyclones to uncertainties of the initial conditions and the model formulation of physical processes.

Code has been developed to generate synthetic observations.

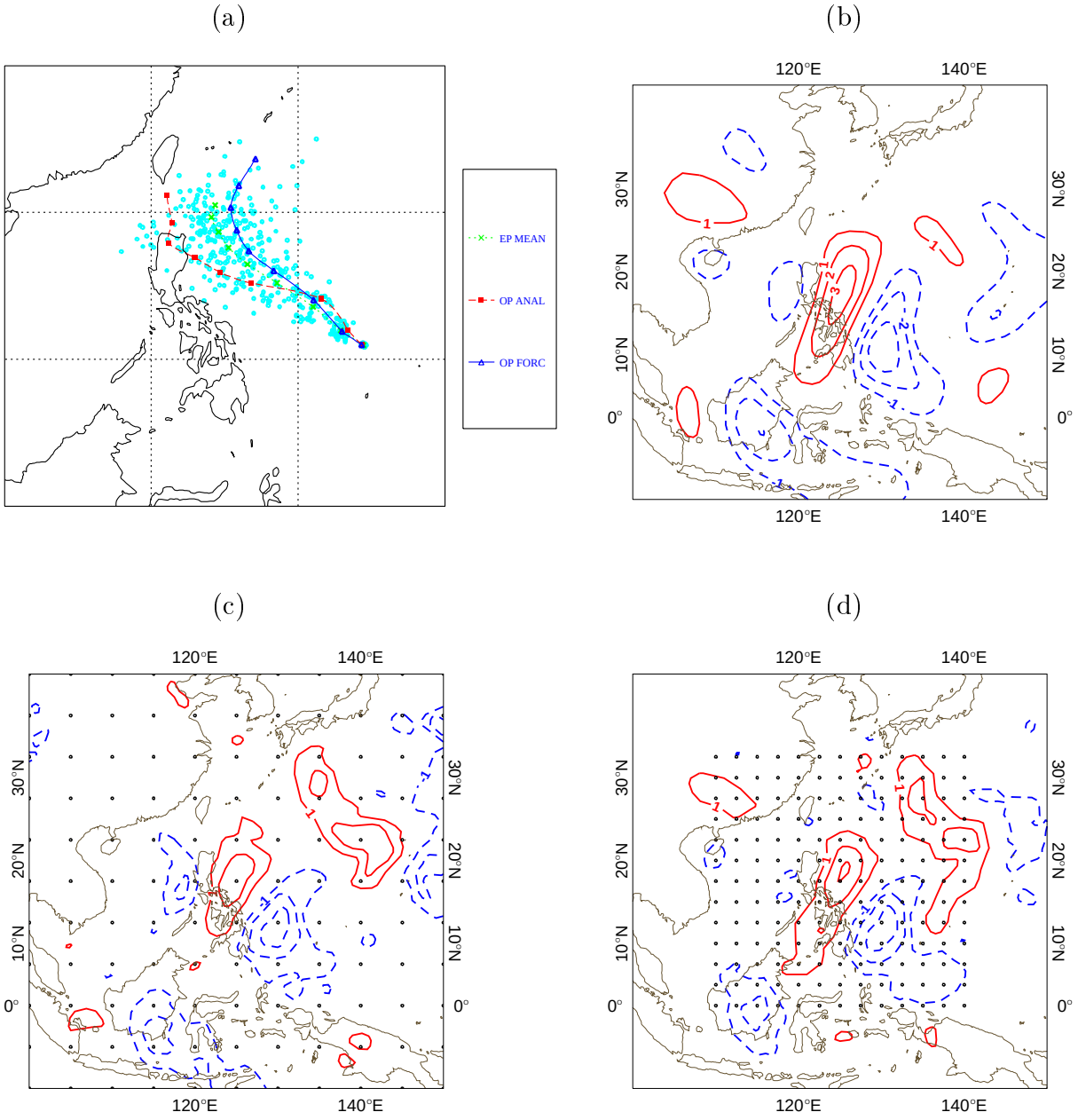
4DVAR-assimilation experiments with conventional data and synthetic observations have been performed for tropical cyclone Zeb hitting the Phillippines in October 1998. The extent of the area where additional observations are made and the spatial density of the observations were

varied. Two sets of assimilations were performed. One had the standard observation error of radiosondes and the other used half of that observation error for the synthetic observations.

RESULTS

The study by Puri et al. (1999) shows that the spread of tropical cyclone tracks in an ensemble depends crucially on how the perturbations of the initial conditions are generated. Singular vectors that are targeted on an area around the cyclone are required to generate adequate spread given an amplitude of the initial perturbations of similar size to the estimated analysis error. Furthermore Barkmeijer et al. (1999) show that the structure of the singular vectors changes significantly if moist processes are included in the formulation of the linearized model.

A series of assimilation experiments for the case of tropical cyclone Zeb reveals the sensitivity of the initial conditions to different sampling and assimilation techniques. Panel (a) shows the ensemble forecast of cyclone tracks using diabatic singular vectors targeted on the cyclone. The observed track lies within the ensemble. Panel (b) shows the mid-tropospheric perturbation of the meridional wind component for the ensemble member which we chose to label truth (its track was closest to the observed track). This structure was computed using singular vectors targeted on the area from 0°–30° N and 110°–140° E. Moist processes where included in the linearized version of the model and the total energy norm was used to measure initial and final amplitude of the perturbations. From this ensemble member synthetic observations are generated and assimilated. Synthetic observations at a horizontal resolution of $5^\circ \times 5^\circ$ are sufficient to reproduce the perturbations of the meridional wind component (Panel c). When the horizontal resolution is doubled the response is very similar (Panel d). However, the denser observation network is required to reproduce the zonal wind perturbations of the best ensemble member. The impact of these synthetic observations on the forecast of the cyclone track is currently investigated.



Track of tropical cyclone Zeb (panel a) based on operational analyses (dashed line), operational forecasts (solid line), ensemble means (dotted line) and individual ensemble members (dots). The tracks are over four days, positions are plotted every 12 hours and are based on tropical singular vectors [from Puri et al. 1999]. Perturbations of meridional wind component at 500 hPa for October 11, 1998, 1200 GMT (Panels b–d). Shown is (b) the perturbation of the initial condition of the best ensemble member and (c) the corresponding perturbation when synthetic observations from this ensemble member are used in the assimilation. Synthetic observations of wind and temperature are taken at 169 locations (marked by dots) and five pressure levels (1000, 850, 700, 500, 200 hPa). The spacing of the synthetic soundings is 5° covering a domain of 60°×60° in latitude and longitude. (d) as (c) but 169 observation at a spacing of 2.5° on a domain of 30°×30°. Contour interval 1 m s^{-1}, negative contours dashed.

IMPACT/APPLICATIONS

This study may help transform the method by which atmospheric observations are taken.

RELATED PROJECTS

The techniques described in this report could be utilised in the proposed THORPEX experiment.

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